Original article

Interchangeability of two tracking systems to register physical demands in football: multiple camera video versus GPS technology

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Summary

The main aim of this investigation was to study the agreement between the distances covered at various speeds by professional soccer players in official matches using a Video-based system (VBS) and a Global Position System (GPS), and to create equations that predict distances from those obtained by other technologies. For these purposes twelve professional soccer (La Liga Santander) players' activities in official matches were registered simultaneously with a semi-automatic multiple-camera or VBS (TRACAB®, system offered by Mediacoach®) and GPS (GPEXE®, Exelio, Udine, Italia). The measured variables were the distance covered by the players at various speeds ranges such as: <7, from 7 to 14, from 14 to 21, from 21 to 24, and >24, (all in km•h^{-1}) and as well several time slots (15, 30 and 45 minutes) were considered. The agreement between the distance recorded by VBS and GPS was studied using the Bland-Altman method. Furthermore, calibration equations using linear regression models were calculated in order to allow interchangeability of data from VBS to GPS and viceversa. The results showed that the agreement between VBS and GPS was low due to elevated systematic (from 3.3 m to -164.4 m) and random error (from 29.3 m to 274.8 m). VBS measured systematically more distance that GPS and the difference between VBS and GPS tended significantly to rise as the distance increased. However, the calibration equations were significant ($p<0.05$) and predicted the distance from one system to another well (R^2= 0.55-0.90). In conclusion, the distance recorded by VBS and GPS cannot be used interchangeably and the calibration equations provided by this study should be used to compare or exchange distances between the two systems.

Key words:
External load. Match analysis. Agreement. Calibration equations. Elite.

Intercambiabilidad de dos sistemas de seguimiento para registrar las demandas físicas en el fútbol: video cámara múltiple versus tecnología GPS

Resumen

Los objetivos de este estudio han sido estudiar el grado de acuerdo entre las distancias recorridas a diferentes velocidades por jugadores profesionales del futbol (La Liga Santander) registradas por el sistema semiautomático de multi-cámara (VBS) y el Sistema de Posicionamiento Global (GPS), y encontrar ecuaciones de calibración entre los dos sistemas. Para ello se registraron las actividades de once jugadores profesionales de fútbol en partidos oficiales simultáneamente con el VBS (TRACAB®, system offered by Mediacoach®) y GPS (GPEXE®, Exelio, Udine, Italia). Las variables medidas fueron la distancia recorrida por los jugadores en diferentes rangos de velocidad, tales como: <7, de 7 a 14, de 14 a 21, de 21 a 24, y >24, (todos en km•h^{-1}) considerándose varios intervalos de tiempo (15, 30 y 45 minutos). El acuerdo entre la distancia registrada por VBS y GPS se estudió utilizando el método de Bland-Altman. Además, las ecuaciones de calibración, usando modelos de regresión lineal, se calcularon para permitir la intercambiabilidad de datos del sistema semiautomático a los GPS y viceversa. Los resultados mostraron que el acuerdo entre VBS y GPS fue bajo debido a un elevado error sistemático (de 3.3 m a -164.4 m) y aleatorio (de 29.3 m a 274.8 m). VBS midió sistemáticamente más distancia que GPS y la diferencia entre VBS y GPS tendió a aumentar significativamente a medida que aumentó la distancia recorrida. Sin embargo, las ecuaciones de calibración fueron significativas ($p<0.05$) y predijeron bien la distancia de un sistema a otro (R^2= 0.55-0.90). En conclusión, la distancia registrada por VBS y GPS no se puede utilizar de manera intercambiable y las ecuaciones de calibración proporcionadas por este estudio se podrían usar para comparar e intercambiar las distancias entre los dos sistemas.

Palabras clave:
Carga externa. Análisis de competición. Ecuaciones de calibración. Élite

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Introduction

Monitoring and management of the athletes' workloads has been in the spotlight in recent years[1]. It is important to monitor individual load during training sessions and matches for several reasons: improved performance, management of load distribution, injury prevention and coach feedback[2]. Athletes participating in elite sports are exposed to high workloads and increasingly saturated competition calendars, so poor load management is one of the major risk factors of injury[3].

The analysis of soccer player activity during matches and /or training sessions have been studied using different techniques and instruments[4]. If we refer to the level of human participation in the process of coding and recording the movements of athletes, we could talk about: a) manual technique, which include using pen and paper, accounting for strides, tape recorder usage, observation software or digitizing tablets carry out the recording with greater personal involvement[5]. This technique requires certain inference from the observer to encode and later register the physical variables[6]; b) A second technique, vision-based systems (VBS), using semi-automatic procedures for monitoring players, and where the support of video playback is indispensable and the interpretive work of the behaviour is largely reduced[7] and, finally; c) the third type, the one which uses radiofrequency or telemetry (such as, Global or Local Positioning Systems, GPS or LPS, respectively). This technique allows automatic tracking and monitoring of the movements of players without the intervention of 'intermediaries'. Technology such as GPS and other micro-technology (e.g., accelerometer, gyroscope and magnetometer) produces a plethora of variables enabling practitioners to quantify training load in more detail than ever before[8].

New technology and analytical methods have led to new possibilities on how to monitor load. Currently in high performance, the player activity analysis during matches and/or training sessions can be measured by different tracking technologies[9], such as GPS, LPS and VBS. The recent incorporation of GPS technology in other sports have also led researchers to study their reliability and validity in different settings[10]. The results of this studies showed that the reliability these devices is better in high frequencies[11] when the distance is linear, but not at maximum speeds[12]. Nevertheless, when movement involves high acceleration[13] and/or change of direction[14] patterns, the accuracy could be compromised. On the other hand, LPS uses infrastructure installed in the same place (usually in indoor) without satellites' connection need. This system has several advantages, e.g., high sampling rates, miniaturization of the devices, more accurately[15]. Finally, the VBS monitors the movements of every player and the ball by sampling activity for up to 25 times per second[7]. Although VBS has been used to study the demands of competition in numerous research studies, the reliability and validity of some semi-automatic tracking products has been scarcely and poorly studied[16]. Most of deficiencies of these studies are placed in the statistical analyses used to assess accuracy, reliability, and validity of the tracking systems[17,18].

Despite the fact that the use of GPS devices is currently allowed in official matches (FIFA, 2015)[19], the most players do not wear it as they feel is uncomfortable and might affect their performance (personal communication from professional players). Consequently, teams monitor training load and friendly matches using GPS technology, while the activity of official matches is monitored through VBS (usually is a company who offers the service, such as TRACAB® or ProZone®). Therefore, in order to carry out an adequate management of the workload we must be able to integrate both training and match load. For example, for an adequate use of the acute:chronic load ratio for a longitudinal assessment of workload it is necessary to introduce in the model both training and match loads[20], because load management is emerging as one of the main risk factors in no contact injuries[1]. This workload should be included in return to play decision-making process[21] so it is essential to be able to integrate and compare GPS and VBS data.

Increasingly national leagues have agreements with companies that analyze team´s match loads (TRACAB®, OPTA®, INSTAT®, ProZone®...) and the use of this type of technology will be accessible to all teams belonging to La Liga. Therefore, it becomes relevant to study the relationships between variables registered by different VBS and GPS systems. The interchangeability and comparison between systems would be also applicable in talent identification programs. When a sport club is interested to know the activity of a young athlete in competition (measured with GPS) and compare it with professional player´s activity (measured through VBS) interchangeability and comparability plays a key role.

For these reasons systems interchangeability could be a timely solution for fitness coaches. The agreement between semi-automatic VBS and GPS has been examined in different studies[22-24]. All of them showed that both systems do not adjust well enough and so the data interchangeability has to be done carefully and comparison of the outcomes. Randers *et al*.[24] and Buchheit *et al.*[22] compared four systems in friendly match and training tasks respectively, showing big differences in some variables such as total distance and distance covered at high speeds. The studies showed that there is less agreement in velocity than in distance, and that these difference tend to increase as the magnitude (distance and time) increases. The advantage of Buchheit *et al.*[22] is that they provided calibration equations that can be used to predict the results that could be expected with a given system from the data collected by another system.

Accordingly, the primary aim of this study was to determine the agreement between VBS and GPS quantifying the amount of systematic and random errors between the distances covered by professional soccer players at various speeds and time slots. We hypothesize the correlation between two systems will be adequate so, the second aim of this research was to create an equation that predicts the distances from VBS to GPS data and vice versa.

Material and method

Participants

Twelve professional male soccer players (25.0±4.0 y, 76.9±6.8 Kg, and 184.1±6.4 cm) from La Liga Santander, Spain's top soccer league were monitored during three official matches, placed in the middle of the first round of the championship, during the 2016-17 season. In total, 116 records of 15-minute slots, 52 of 30-minute slots and 15 of 45-minute slots were analysed. The study was conducted in accordance to the Declaration of Helsinki (2008), and the Ethics Committee of the

University of the Basque Country (CEISH) giving institutional approval for the study (CEISH/235).

Variables

Similar to previous works[25,26], the variables analyzed were the distances covered by players during official matches at various speed ranges: total distance (TD) and distance covered at less than 7.3 km•h^{-1} (0to7), between 7.3 to 14.0 km•h^{-1} (7to14), between 14.0 to 21.0 km•h^{-1} (14to21), between 21.0 to 24.0 km•h^{-1} (21to24), and at more than 24.0 km•h^{-1} (>24).

Both GPS and VBS systems registered the distance in 15-minute time slots (e.g., 0-15', 16-30', 31-45', 46-60', 61-75' and 76-90'). Only periods that the player completed were included in the analysis. The analysis performed in 15-minute, 30-minute and 45-minute time slots at the above-mentioned speeds that are commonly used in football match analysis to assess performance or fatigue[27-29].

Procedure

The players wore the same device of GPEXE PRO (Exelio, Udine, Italia, GPEXE®) and were also tracked using the TRACAB® system managed by Mediacoach® on each match. Each GPS unit was placed between shoulder blades using a specially designed vest. In accordance with the manufacturer's instructions, GPS devices were activated 15 min prior to the start of the match. At the end of the match, data from GPS was downloaded to a PC and processed using the software provided by GPEXE® (The Power Tracker for GPEXE). The GPS files were manually cut considering the starting point the displacement of the players at the beginning of the match. From this starting point, 15-minute time slots were stablished. No extra time was included for analysis. In order to assess the reliability of this procedure all GPS data was processed by two independent researchers. A high correlation coefficient (0.94) was found between the two and therefore the data from one of the researchers was included in the study. The VBS data was provided by TRACAB® (managed by Mediacoach®, Mediapro®, España).

Data analysis

To determine the agreement (the amount of systematic and random error) between VBS and GPS, the Bland and Altman method[30] was used. Repeatability coefficient (RC), bias or systematic error (SE), lower and upper limits of agreement (LOAs) and upper and lower confidence intervals at 95% for SE and LOAs were calculated. These results were accompanied with Bland-Altman plots. This analysis was performed using the MedCalc® program for Windows version 12.2.1.0 (Medcalc software, Mariakerke, Belgium). To determine whether the systematic error between devices was significant, a paired t-test was performed. In order to check that there was no relationship between the difference between systems (VBS *vs* GPS) and the magnitude (distance) Bland-Altman plots were checked and a linear regression was also performed[31]. In the regression analysis the difference between systems was defined as the dependent variable and the mean of both systems as the independent variable. The significance level for the t-test and the regression was set *a priori* at $p<0.05$.

In order to create an equation that would allow for predicting the distance from one system to another, linear regression equations were created. These equations would allow for converting the distance registered from GPS to VBS or vice versa.

$$GPS = a+b\ (VBS)$$

$$VBS = a+b\ (GPS)$$

The significance level for this regression analysis was set *a priori* at $p<0.05$. The typical error of the estimate (TEE) or the residual standard error and adjusted R square were also calculated. Paired t-test analyses and all regression analyses were conducted in R (3.3.3 version) using base package and R studio (1.0.136 version).

Results

Descriptive analysis

In the Table 1 it can see the descriptive values, mean and standard deviation (sd) in meters, for each time slot and tracking system (VBS and GPS) considering the different velocity ranges.

Agreement between VBS and GPS

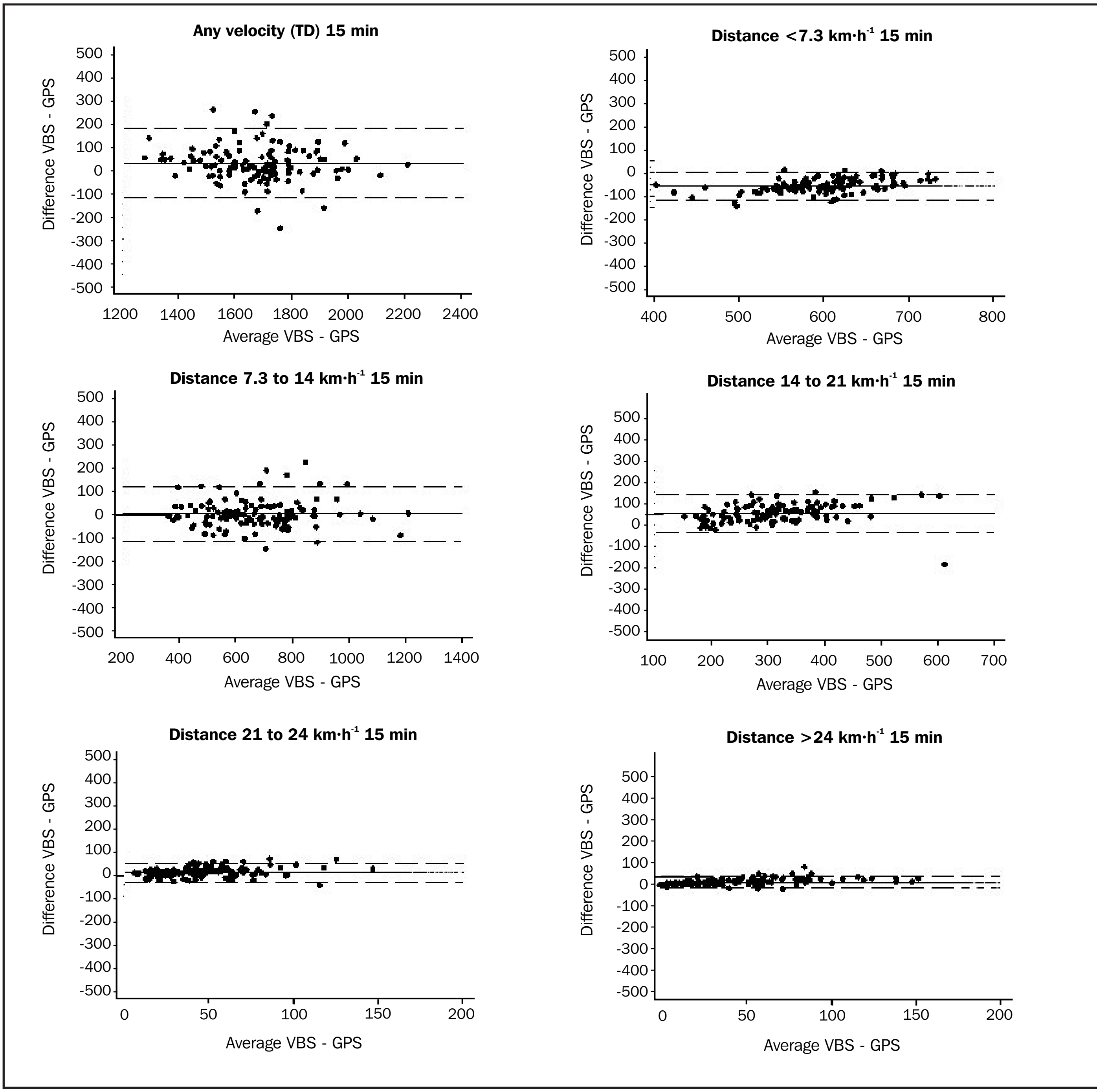
As for the systematic error, Bland-Altman analysis showed that VBS tends to measure systematically more distance that GPS at all speeds (except from 0 to 7.3 km•h^{-1} where GPS measure more than VSB) in the three time slots analysed in this study (Figures 1, 2 and 3). According to

Table 1. Descriptive values (mean and standard deviation, sd) in meters, for each time slot and tracking system (VBS and GPS) considering the different velocity ranges.

		VBS		GPS	
Time Slot	**Velocity range**	**mean**	**sd**	**mean**	**sd**
15 min	TD	1685.4	296.4	1663.4	316.2
	0to7	568.7	70.6	627.5	56.0
	7to14	678.2	170.3	663.1	168.6
	14to21	335.3	97.0	283.3	78.2
	21to24	48.9	30.9	45.6	25.6
	>24	52.6	39.0	38.6	32.0
30 min	TD	3399.2	296.4	3357.2	316.2
	0to7	1130.4	127.5	1250.3	98.2
	7to14	678.2	170.3	663.1	168.6
	14to21	335.3	97.0	283.3	78.2
	21to24	48.9	30.9	45.6	25.6
	>24	52.6	39.0	38.6	32.0
45 min	TD	5106.1	445.0	5079.3	447.9
	0to7	1743.0	172.9	1907.4	150.8
	7to14	678.2	170.3	663.1	168.6
	14to21	335.3	97.0	283.3	78.2
	21to24	48.9	30.9	45.6	25.6
	>24	52.6	39.0	38.6	32.0

VBS is video-based system (TRACAB®) and GPS is global position system (GPEXE®).

Figure 1. Bland-Altman plots VBS vs GPS at 15 minutes time slot.

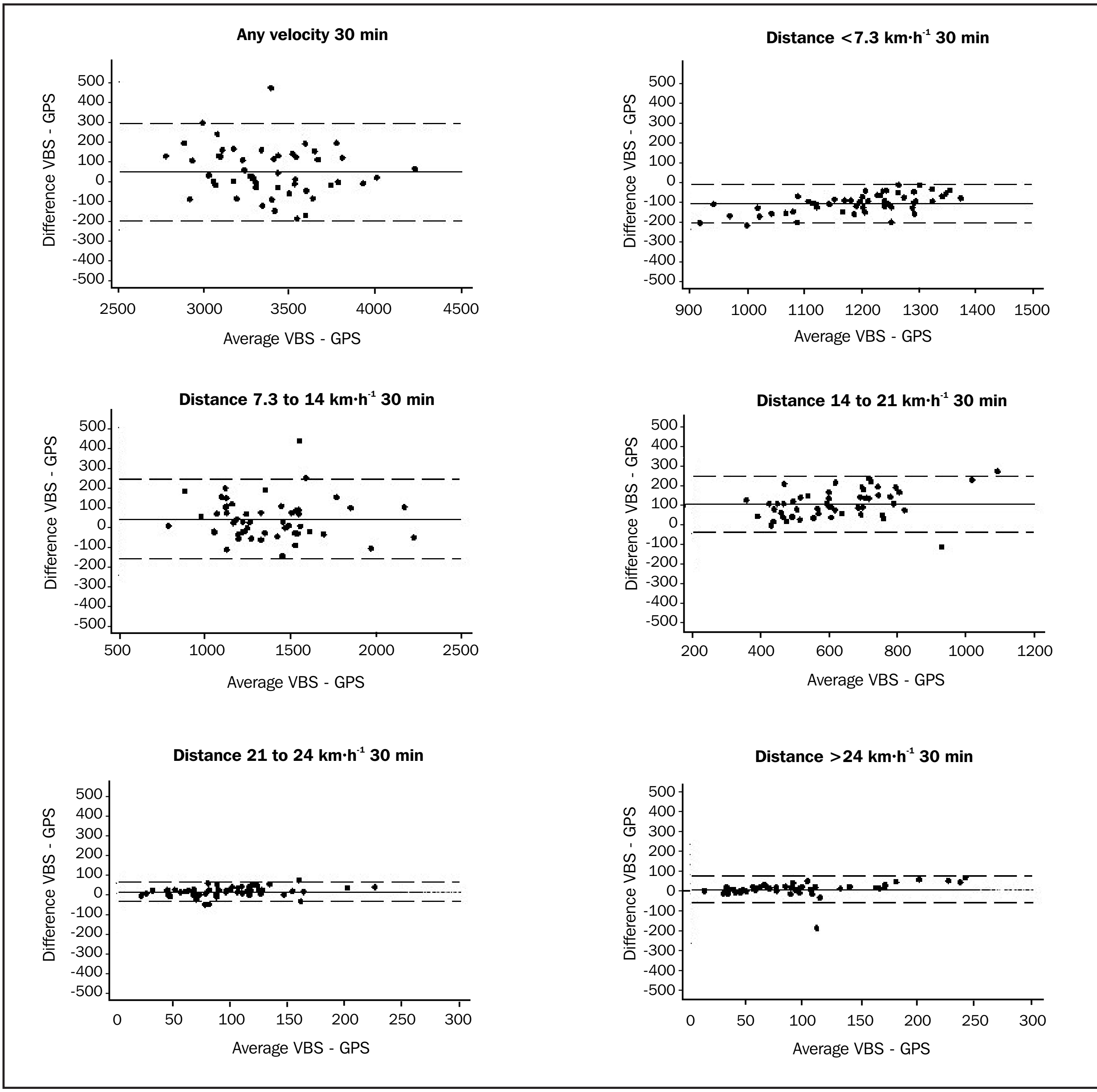


TD: Total distance.

paired t-test, this differences were all significant for the 30 *minute time slots and 5 out of 6 15-minute time-slot speeds* ($p<0.05$). In the 45-minute time slot two speeds had a significant systematic error, 0 to <7.3 km•h^{-1} and 14.0-21.0 km•h^{-1} (Table 2).

The random differences between VBS and GPS (Table 2) varied from 148.1 m (TD) to 29.3 m (>24 km•h^{-1}) in the 15-minute time slot. In the 30-minute time slot the random error (repeatability coefficient) varied from 246.4 m (TD) to 48.8 m (21to24 Km•h^{-1}). The repeatability coefficient was from 274.8 m (TD) to 55.9 m (21to24 km•h^{-1}) in the 45-minutes slot. Regression analyses demonstrated that there was a tendency in the differences between VBS and GPS to increase when the measured magnitude (distance) was bigger. This was more common in the 15-minute slot (4 out of 6 analyses) than in 45-minute slot (2 out of 6 analysis) (Table 2).

Figure 2. Bland-Altman plots VBS vs GPS at 30 minutes time slot.



TD: Total distance.

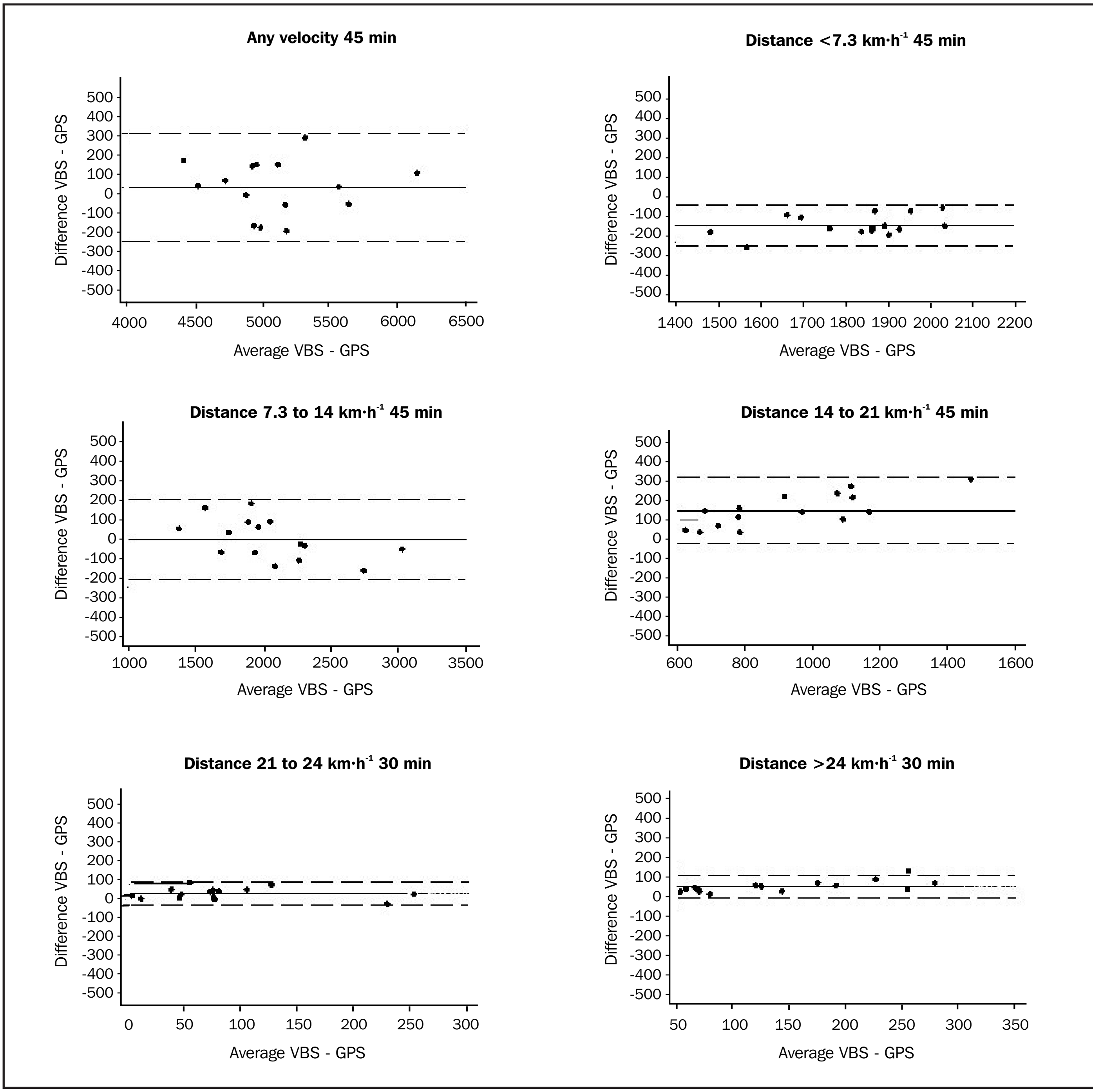
VBS and GPS prediction equations

All the prediction equations calculated in the present study are displayed in Table 3. The prediction equations calculated in this study appeared to be significant (Table 3). The adjusted R^2 was from 88% to 54% in the 15-minute time slot, 88% to 71% in the 30-minute time slot and from 95% to 84% in the 45-minute slot.

Discussion

The main aim of this investigation was to study the agreement between the distances covered at various speeds by professional soccer players in official matches using VBS and GPS, and create equations that predict distances from those obtained by other technologies. The results of the analysis showed that distances recorded by the two sys-

Figure 3. Bland-Altman plots VBS vs GPS at 45 minutes time slot.



TD: Total distance.

tems differed substantially and cannot be used in an interchangeable manner. However, prediction equations created in this study predicted the distance from one system to another.

As for the agreement between the systems, this study found that during official matches, the different metrics collected by the two systems differed substantially. These results are in line with other studies[22-24] that also indicated that the GPS measures less than the video-tracking. According to the analysis, the systematic error demonstrated that there is a tendency in VBS to measure more distance in all speeds and time slots than GPS, and these differences appeared to be significant in the majority of cases. It is important to mention that there was an exception to this rule in the 0 to 7 km•h^{-1} speed. In this case, GPS overestimates

Table 2. Agreement analysis between VSB and GPS.

Time Slot	Velocity range	Systematic error	Systematic error CI 95%	Paired t-test	Repeatability coefficient	LOA lower	LOA lower CI 95%	LOA upper	LOA upper CI 95%	Regression p-value
15 min	TD	22.0	8.1 to 35.9	0.002	148.1	-126.1	-149.9 to -102.3	170.1	146.3 to 193.9	NS
	0to7	-58.8	-64.3 to -53.3	0.000	58.5	-117.3	-126.7 to -107.9	-0.3	-9.7 to 9.1	0.000
	7to14	15.1	4.2 to 26.0	0.007	116.1	-100.9	-119.6 to -82.3	131.2	112.5 to 149.8	NS
	14to21	49.9	41.8 to 58.1	0.000	86.4	-36.4	-50.3 to -22.5	136.3	122.4 to 150.2	0.006
	21to24	3.3	-0.5 to 7.2	NS	41.0	-37.7	-44.3 to -31.1	44.3	37.7 to 50.9	0.004
	>24	14.1	11.3 to 16.8	0.000	29.3	-15.2	-19.9 to -10.5	43.3	38.6 to 48.0	0.000
30 min	TD	42.0	7.0 to 77.0	0.020	246.4	-204.4	-264.6 to -144.2	288.4	228.2 to 348.7	NS
	0to7	-119.9	-133.5 to -106.3	0.000	96.0	-215.9	-239.4 to -192.5	-23.9	-47.3 to -0.4	0.000
	7to14	33.7	5.0 to 62.5	0.022	202.3	-168.6	-218.0 to -119.2	236.0	186.6 to 285.5	NS
	14to21	97.2	77.3 to 117.1	0.000	140.1	-42.9	-77.2 to -8.7	237.3	203.1 to 271.5	0.010
	21to24	8.1	1.2 to 15.0	0.023	48.8	-40.7	-52.6 to -28.8	56.9	44.9 to 68.8	0.020
	>24	22.9	13.4 to 32.5	0.014	67.4	-44.4	-60.9 to -27.9	90.3	73.8 to 106.8	0.011
45 min	TD	26.80	-50.8 to 104.4	NS	274.8	-247.9	-383.7 to -112.2	301.6	165.8 to 437.4	NS
	0to7	-164.38	-194.1 to -134.7	0.000	105.1	-269.4	-321.3 to -217.5	-59.3	-111.2 to -7.4	NS
	7to14	-3.91	-61.9 to 54.1	NS	205.2	-209.1	-310.5 to -107.7	201.3	99.9 to 302.7	0.036
	14to21	144.02	96.8 to 191.2	0.013	167.1	-23.1	-105.7 to 59.5	311.1	228.6 to 393.7	NS
	21to24	6.77	-9.0 to 22.6	NS	55.9	-49.2	-76.8 to -21.5	62.7	35.1 to 90.3	NS
	>24	44.29	27.5 to 61.1	NS	59.4	-15.1	-44.4 to 14.3	103.7	74.3 to 133.0	0.007

CI 95%: confidence interval at 95%, LOA: limit of agreement, NS: Non-significant, TD: Total distance.

Table 3. Equations between the two different technologies (GPS and VBS) during official matches in all velocity ranges.

Time slot	Range of speed	VBS to GPS		GPS to VBS		Adjusted R^2	p-value
	($Km \cdot h^{-1}$)	Formula	TEE	Formula	TEE		
15 min	TD	G = 65.2+(V*0.948)	75.36	V = 230.6+(G*0.875)	72.38	0.83	0.001
	0to7	G = 215.0+(V*0.725)	22.78	V = (-154.7) + (G*1.153)	28.72	0.83	0.001
	7to14	G = 32.6+(V*0.930)	58.24	V = 49.3+(G*0.948)	58.83	0.88	0.001
	14to21	G = 19.6+(V*0.794)	39.31	V = 48.3+(G*1.006)	44.26	0.79	0.001
	21to24	G = 15.5+(V*0.615)	17.29	V = 8.2+(G*0.892)	20.82	0.55	0.001
	>24	G = (-1.6)+(V*0.763)	11.79	V = 8.9+(G*1.134)	14.37	0.86	0.001
30 min	TD	G = 29.7+(V*0.979)	126.80	V = 510.7+(G*0.860)	118.90	0.84	0.001
	0to7	G = 433.0+(V*0.723)	34.31	V = (-392.0)+(G*1.218)	44.52	0.88	0.001
	7to14	G = 24.5+(V*0.958)	103.50	V = 139.3+(G*0.922)	101.50	0.88	0.001
	14to21	G = 49.4+(V*0.783)	61.37	V = 60.3+(G*1.064)	71.55	0.83	0.001
	21to24	G = 20.2+(V*0.716)	21.08	V = 6.5+(G*1.017)	25.12	0.72	0.001
	>24	G = 9.0+(V*0.697)	28.50	V = 20.4 +(G*1.031)	34.67	0.71	0.001
45 min	TD	G = 192.6+(V*0.957)	144.10	V = 309.0+(G*0.944)	143.20	0.90	0.001
	0to7	G = 457.2+(V*0.832)	46.74	V = (-344.9)+(G*1.095)	53.61	0.90	0.001
	7to14	G = (-236.2)+(V*1.117)	97.13	V = 288.4+(G*0.858)	85.13	0.96	0.001
	14to21	G = 117.1+(V*0.740)	49.36	V = (-96.8)+(G*1.279)	64.92	0.94	0.001
	21to24	G = (-4.2)+(V*0.981)	29.58	V = 24.0+(G*0.868)	27.83	0.84	0.001
	>24	G = (-2.758)+(V*0.750)	20.70	V = 16.398+(G*1.229)	26.49	0.92	0.001

G: GPS; V: VBS; TEE: typical error estimated; TD: Total distance.

the distance provided by VBS in all time slots. This might be because the VBS speed range player needs to be running at least 1 second or 1 m in this range of speed before it starts measuring, while GPS devices are constantly receiving displacement when players move. It would be highly recommended (but unlikely) that companies who offer services to Clubs unify criteria to ease the researchers and coaches task when quantifying the workload.

As for the random error, the Bland-Altman analysis showed that the error associated with GPS and VBS was elevated. Moreover, this study also found that the differences between systems tend to increase significantly, when the measured magnitude (distance) increases. In other words, the bigger the distance measured, the bigger the differences between the distances recorded by the systems. This agrees with the fact that the repeatability coefficient increases in all speed ranges as the time slot increases.

Therefore, the distance provided by VBS and GPS are substantially different and cannot be compared directly. However, the prediction equation derived from linear regression analysis was significant with an elevated R^2. In other words, the equation explains well the changes in the dependent variable (one system) from the values in the independent variable (the other system). That means that having data from either GPS or VBS, one could predict the distance that the other system would register with high accuracy.

The use of different tracking systems by professional football clubs justifies the need of being able to exchange the information obtained through VBS and GPS. Converting the information obtained through the VBS into GPS data could be useful in the tracking and management of the workload, and to estimate, for example acute:chronic load. As well to assess if the demands of training tasks replicate the match demands[32,33]. The inverse conversion could also be interesting to know the time of the return to play of an athlete, or what would be the activity of a young club sportsman (measured through GPS technology) compared to a professional (measured through VBS).

In practice (just considering the variable TD), when staff members want to convert match running distances collected with GPS, e.g. 5,000 m in 45 minutes, to VBS-expected distances these equations can be used: if they had worn one of the GPS units the estimated distance should be 4,977.6 m (0.957 x 5,000 m + 192.6 m). Considering the same distance covered by the player (5,000 m), if we wanted to convert from VBS to GPS expected distances the equation should be this, 0.944 x 5000 m + 309.0 m for GPS device, that is, 5,029.0 m.

When comparing the equations proposed per Buchheit *et al.*[22] with the ones of the current study, the relation between both tracking systems is similar. Let's consider the same distance covered by one player that was 5,000 m. The following formulas could be used provided by Buchheit *et al.*[22], GPS = (1.01 x VBS)-70 m or VBS = (0.92 x GPS)+250 m, if VBS was used to register this distance or GPS system, respectively. The GPS-expected distance covered by the player would be 4,980 m (5,029 m in the current study), while the VBS-expected distance ran by the player would be 4,850 m (4,978 m in the current study). In this way, technicians could track the training and match loads considering distances at different speeds. However, other mechanical variables (e.g., acceleration, inertial movements) like level 2 and 3 proposed by Buchheit and Simpson[20] are still without possibilities of transformation due to videotracking systems do not provide information of this type of variables (e.g., inertial movement analysis).

The main limitation of this study is that only two systems were studied (VBS *vs*. GPS) among the vast amount of VBS and GPS systems that the market offers nowadays. However, the two systems studied are two of the most used tracking systems. On the other hand, VBS has stablished that player needs to be running at least 1 second or 1 m before it starts measuring (this is a rule that the company uses) and GPS devices are constantly receiving displacement at any movement. Furthermore, frequency is not the same for both systems. These facts might have affected the agreement between systems. Unfortunately, little can be done to correct this since companies make their decisions based on the market and not on the needs of researchers.

It would be interesting for further research to compare different VDS and GPS systems to help coaches, technical staff and researchers to understand the workload of players measured by different technologies. In the same line, studies in other sports and settings would also be interesting to seize workloads and demands of different sports to adjust properly the workloads and improve physical performance.

Conclusion

The main conclusions of the study are:

- VBS and GPS do not register the same amount of distance in any of the speeds or time slots studied (there was an elevated systematic and random error). Systematically, in most of the speed ranges, VBS register most distance than GPS system. This differences increases when the measured distance is bigger at any speed. The results from VBS and GPS cannot be used interchangeably.
- Prediction equations predict the distance from VBS to GPS and vice versa very well.

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Conflict of interest

The authors do not declare a conflict of interest.

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